# Chapter 12: Freezing Precipitation and Ice Storms

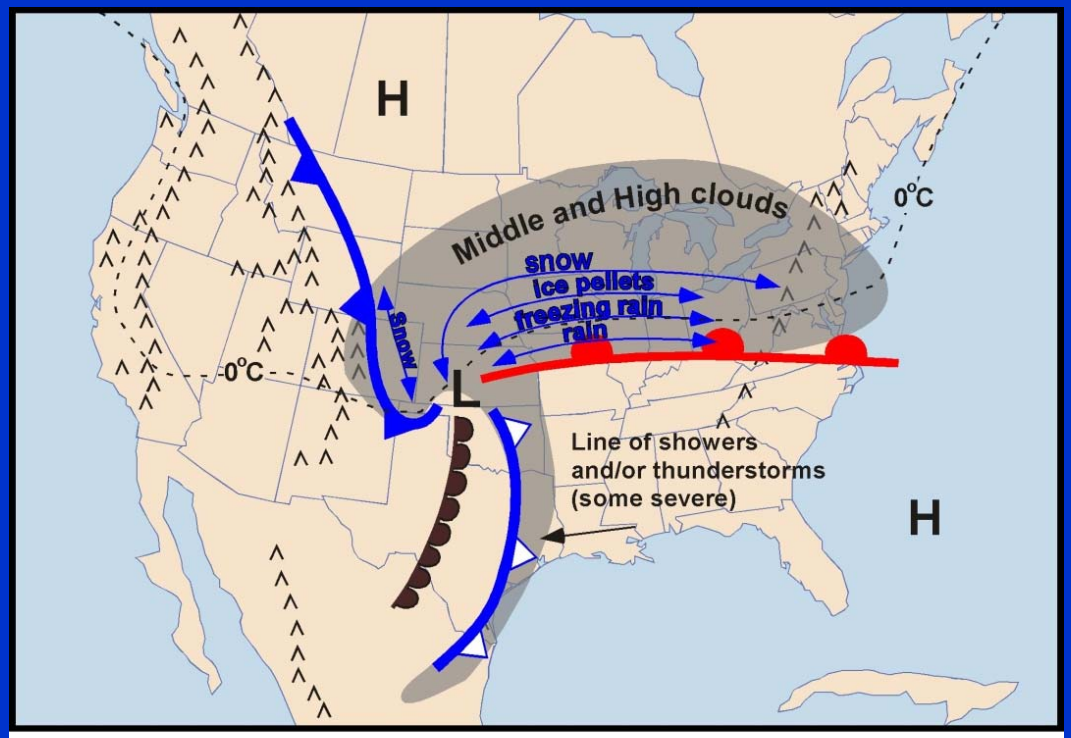
Courtesy: Eric Snodgrass

- Supercooled Water
- Vertical Structure of Freezing Precipitation
- Weather Pattern of Freezing Precipitation
- Distribution of Freezing Precipitation

# Freezing Precipitation

- Freezing precipitation is rain or drizzle that freezes on surfaces and leads to the development of an ice glaze.
- Freezing precipitation is responsible for about 20% of all winter weather-related injuries.
- Freezing precipitation occurs in about a fourth of all winter weather events in the continental US.
- Ice storm is defined as a freezing precipitation weather event with ice accumulation of at least 0.25 in (0.64cm).
- Half of the freezing precipitation events qualify as ice storms.

# Weather / E. Rocky Cyclone





- ***East of the Cyclone***: A wide region of clouds develops north of the warm front. The clouds are deepest close to the surface position of the front and becomes thin and high far north of the front.
- ***Northwest of the Cyclone***: Air north of the cyclone center flows westward and rises on the slope of the Rockies, which produces heavy snow and blizzard conditions along the east side of the Rockies and eastward onto the Great Plains.

# Precipitations

"Precipitation is any liquid or solid water particle that falls from the atmosphere and reaches the ground."

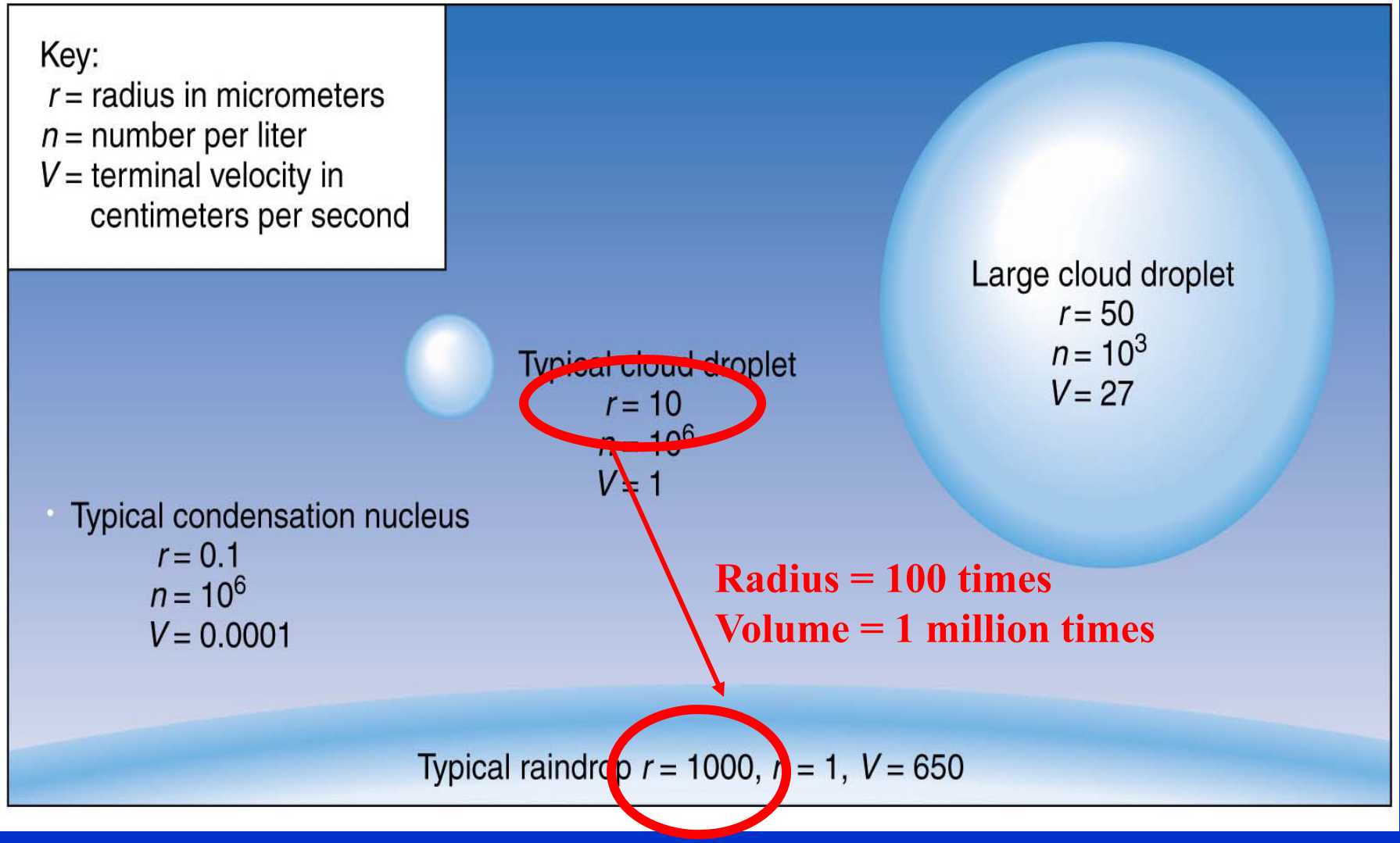
Water Vapor Saturated

↓ Need cloud nuclei

Cloud Droplet formed around Cloud Nuclei

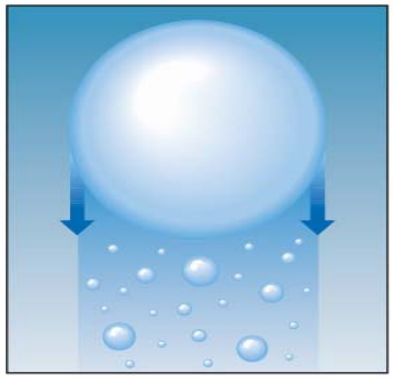
↓ Need to fall down

Precipitation

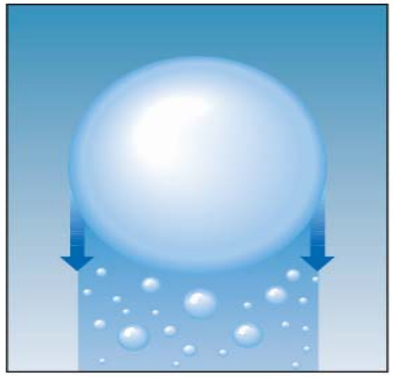

Key:
r = radius in micrometers
n = number per liter
V = terminal velocity in centimeters per second
Large cloud droplet
r = 50
n = 10^3
V = 27
Typical cloud droplet
r = 10
n = 10^6
V = 1
Typical condensation nucleus
r = 0.1
n = 10^6
V = 0.0001
Radius = 100 times
Volume = 1 million times
Typical raindrop r = 1000, n = 1, V = 650

# Growth by Condensation

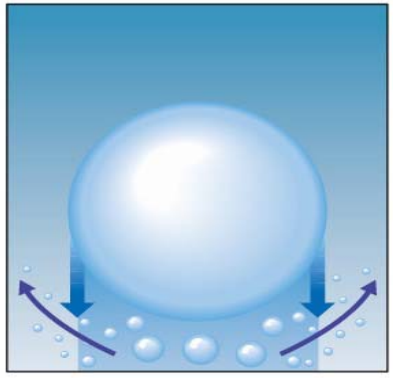
- Condensation about condensation nuclei initially forms most cloud drops.
- Insufficient process to generate precipitation.



(a)



(b)



(c)

# Collision

- Collector drops collide with smaller drops.
- Due to compressed air beneath falling drop, there is an inverse relationship between collector drop size and collision efficiency.
- Collisions typically occur between a collector and fairly large cloud drops.
- Smaller drops are pushed aside.
- Collision is more effective for the droplets that are not very much smaller than the collect droplet.

# Coalescence

- When collisions occur, drops either bounce apart or coalesce into one larger drop.
- Coalescence efficiency is very high indicating that most collisions result in coalescence.
- Collision and coalescence together form the primary mechanism for precipitation in the tropics, where warm clouds dominate.

# Cool and Cold Clouds

- A portion of most mid-latitude clouds have temperatures below the melting point of ice.
- Cold clouds are referred to those have temperature below 0ºC throughout and consist entirely of ice crystals, supercooled droplets, or a mixture of two.
- Cool clouds are referred to those have temperatures above 0ºC in the lower reaches and subfreezing condition above.

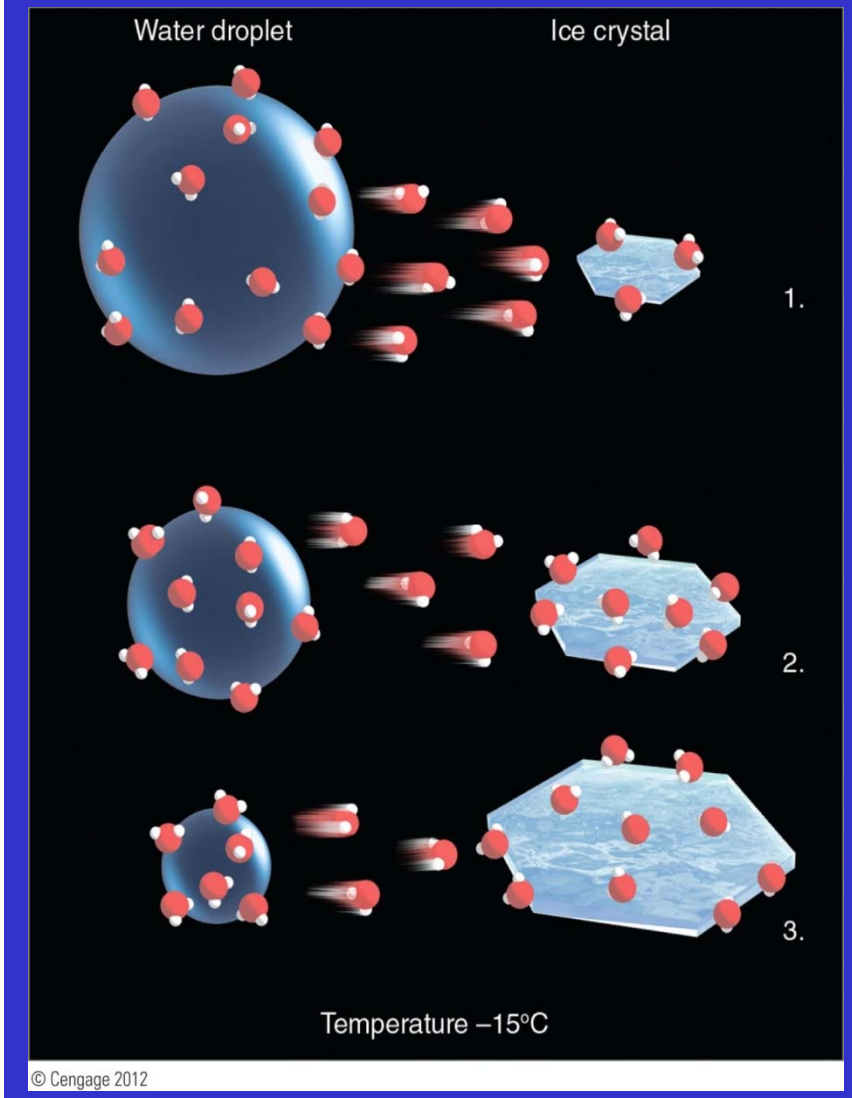
# Supercooled Water

- Ice melts at 0°C, but water does not necessary freeze to ice at 0°C.
- Ice nuclei is needed to help water to get frozen.
- Certain microscopic particles, such as clay, organic particles, or bacteria, have a crystalline structure similar to ice that can allow water molecular to attach to and to build an ice lattice.
- Without enough ice nuclei, water can exist event its temperature is below between 0°C and -40°C, which are called “supercooled water”.
- Supercooled water can result in freezing precipitation when they come in contact with a surface that has a temperature below 0°C.

# Growth in Cool and Cold Clouds

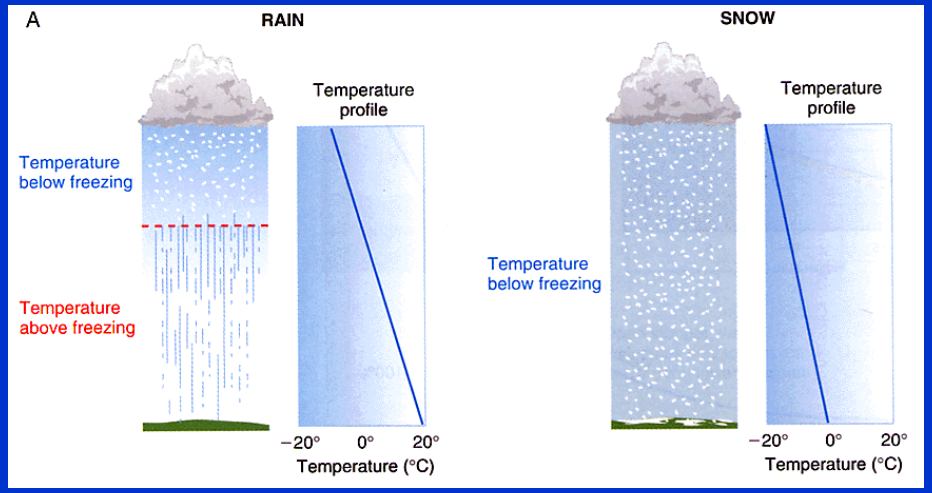
- Cool month mid-latitude and high latitude clouds are classified as cool clouds as average temperatures are usually below freezing.
- Clouds may be composed of (1) Liquid water, (2) Supercooled water, and/or (3) Ice.
- Coexistence of ice and supercooled water is critical to the creation of cool cloud precipitation - the Bergeron Process.

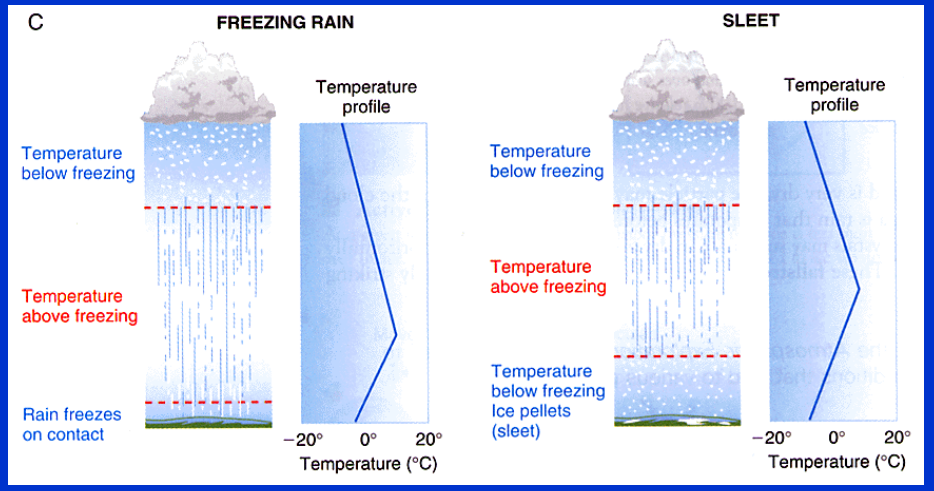
# Bergeron Process




- Saturation vapor pressure of ice is less than that of supercooled water and water vapor.
- During coexistence, water will change directly onto ice.
- Ice crystals grow rapidly at the expense of supercooled drops.
- The ice crystal becomes heavy enough to fall, then the riming and aggregation processes begin.

# Two Ways to Produce Freezing Precipitation



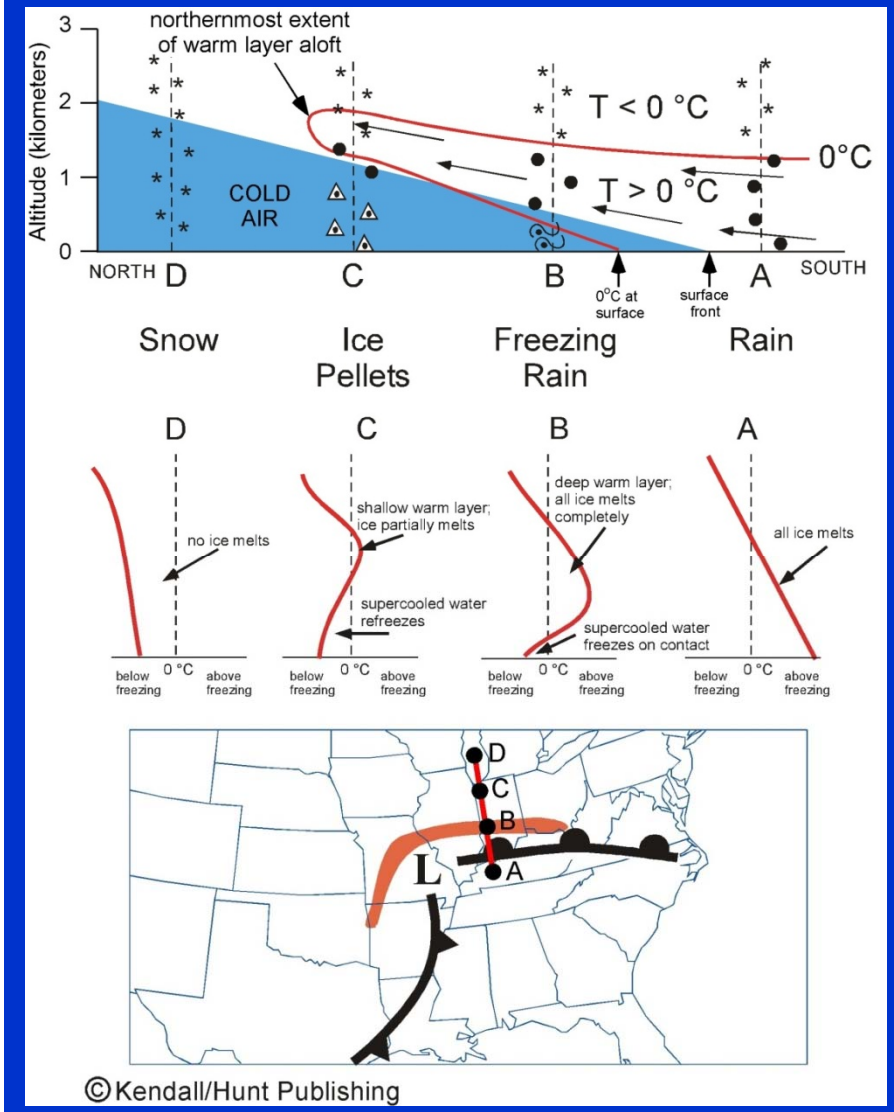




- Melting Process ➔ freezing rain ➔ supercooled water after fall into a subfreezing layer ➔ refreezed after making contact with surface ➔ freezing rain

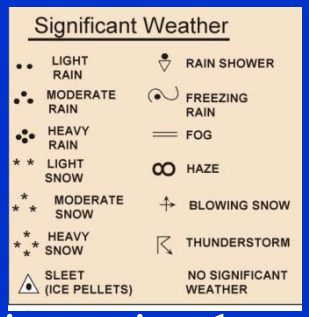
- Supercooled Warm Rain Process ➔ freezing drizzle

  This process occurs in low clouds, where rain is formed through collision and coalescence without involving snow (that is why it is called *warm rain*).

# Cross Section through a Warm Front



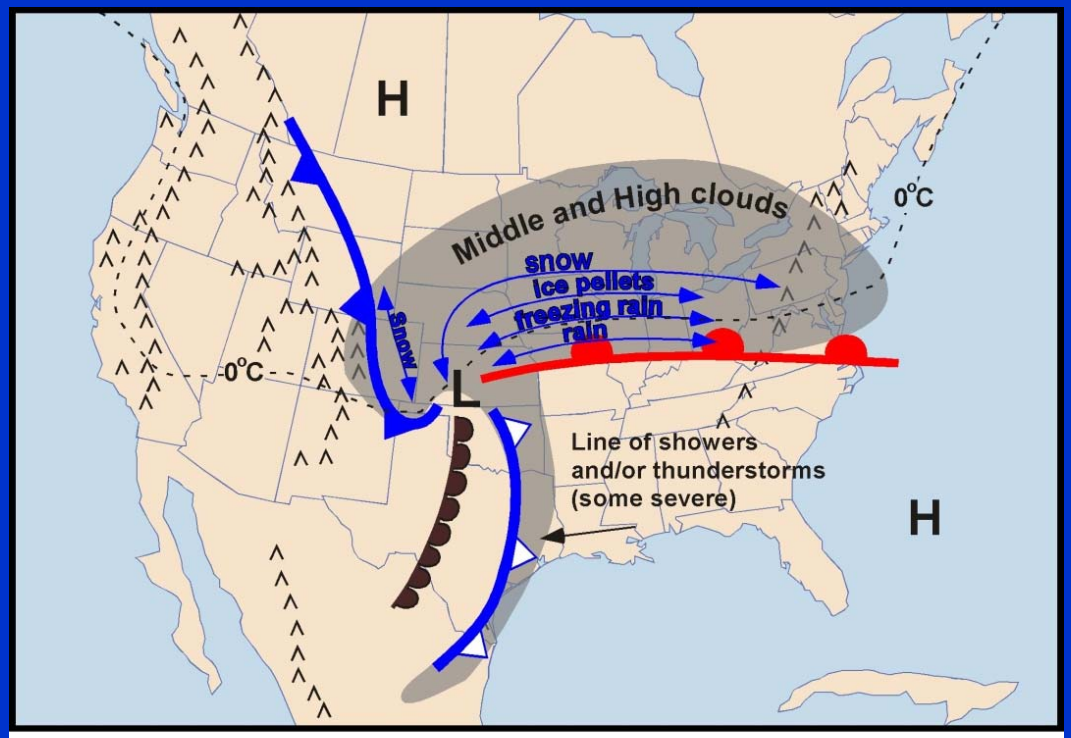

- Temperature inversion is needed for the melting process to occur to produce freezing rain.




- Point D ➔ snow
- Point A ➔ rain
- Point B &C ➔ have inversion layers
- Point B ➔ snow melt in the deep warm inversion layer, supercooled in the near-surface subfreezing layer, and produces ***freezing rain*** when it hit the surface.
- Point C ➔ snow won't melt completely in the shallow inversion layer, refreeze in the near-surface layer, and becomes ***sleet*** (frozon rain droplets) on the surface.

ESS124
Prof. Jin-Yi Yu

# Weather / E. Rocky Cyclone





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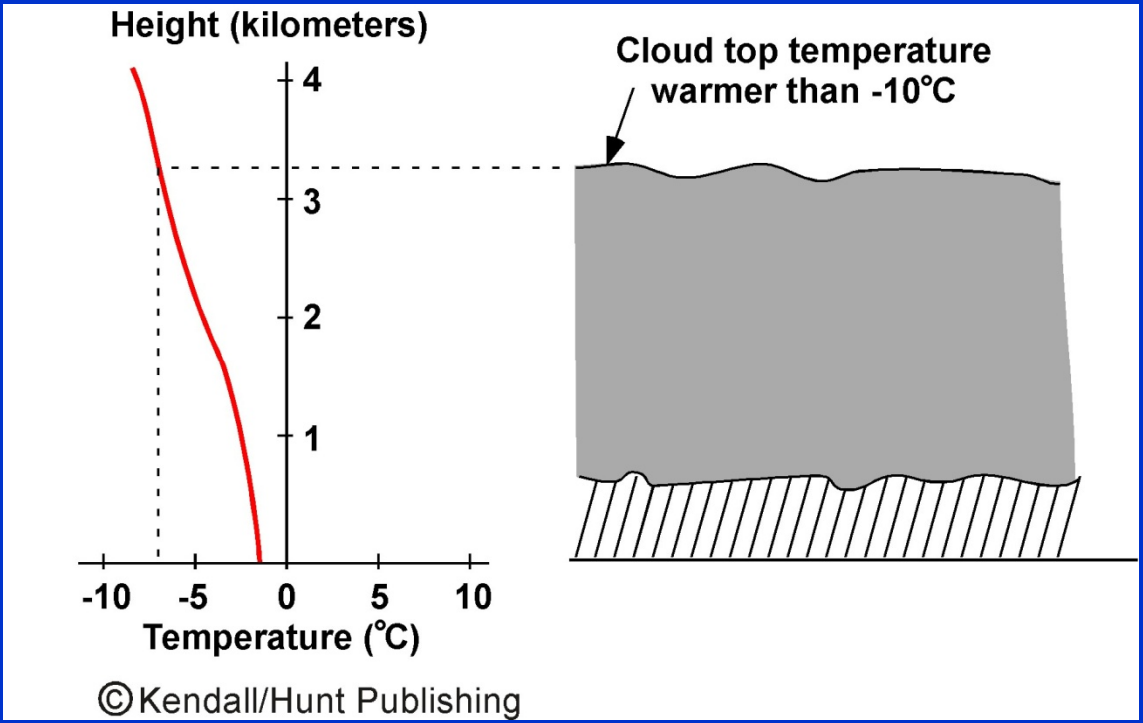
# Freezing Rain and Sleet

(Photographer: Lee Anne Willson)

# Freezing Drizzle

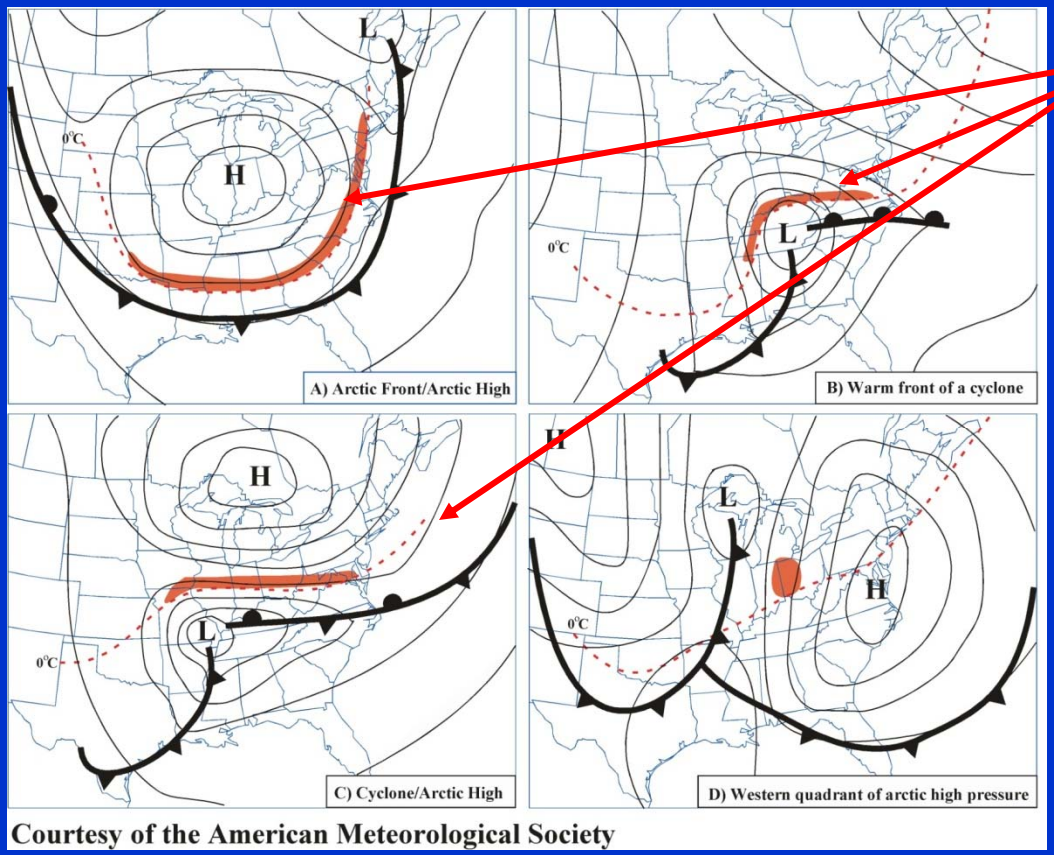



- ***Freezing drizzle***: light, misty precipitation that freezes on contact with surfaces, often formed in ***cold cloud*** layers with depths of 1-3km.
- Drizzle droplet diameter about 0.2-0.5 mm.
- Cloud top temperature should be no colder than -10°C to -15°C, so ice nuclei are not effective and supercoooled droplet can collide to from drizzle.

# Freezing Drizzle and Aviation Safety

- Because of danger of icing, aviation forecasters pay particular attention to situations where freezing drizzle may occur.

# Weather Patterns for Freezing Precipitation

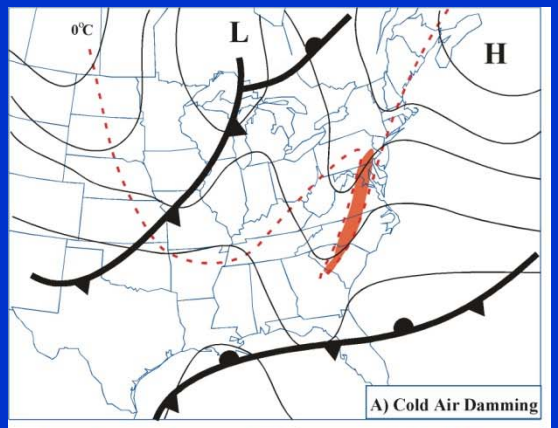


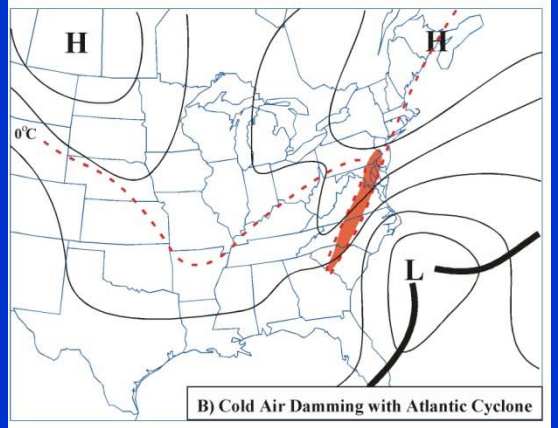

Courtesy of the American Meteorological Society

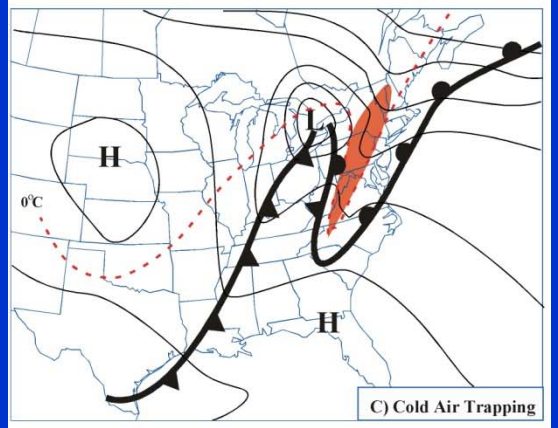
(A) Arctic front (1/3 of all freezing precip. Events east of Rockies).

(B&C) North of a warm front: with (B) or without (C) a high pressure to the North)

(D) Southerly flow west of a high-pressure center ➔ warm moist air over an arctic cold dome




Courtesy of the American Meteorological Society

# Cold Air Damming

- Freezing precipitation occurs frequently along the east side of the Appalachian Mountains associated with the "cold air damming".
- 15% of all freezing precipitation events affecting the US east of the Rockies are due to this process.

(A) The easterlies associated with the high-pressure center over the Atlantic Ocean force the cold arctic air along the coast.

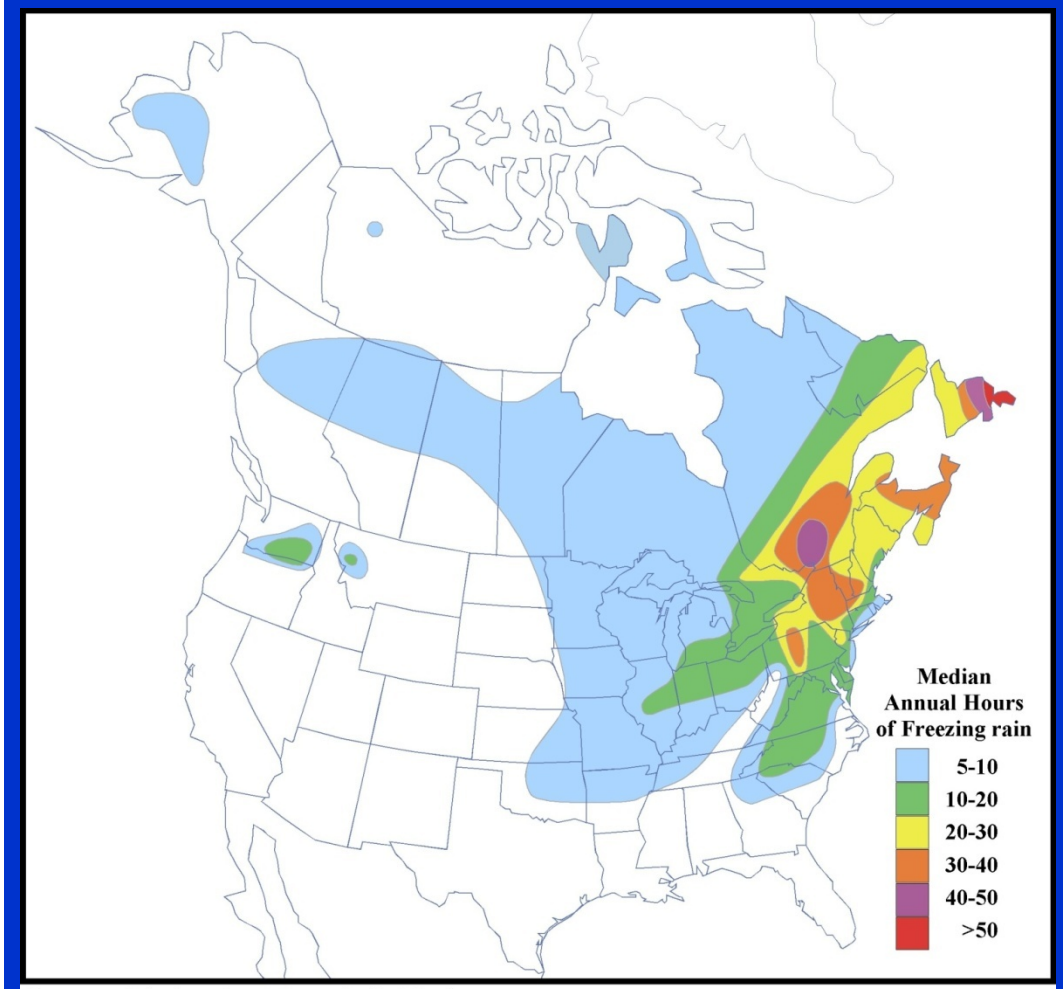
(B) Cyclones develop along the eastern coast of the Gulf of Mexico or Atlantic Coast and move northeastward.

(C) When cyclones east of the Rockies moves toward the Great lakes, the warm front advances on either side of the Appalachian and produces a "cold air trapping".

# Forecasting Freezing Precipitation

- Vertical soundings of temperature and moisture are crucial.
- It is particularly important to pay attention to the presence of any above-freezing layers in the lowest few kilometers.

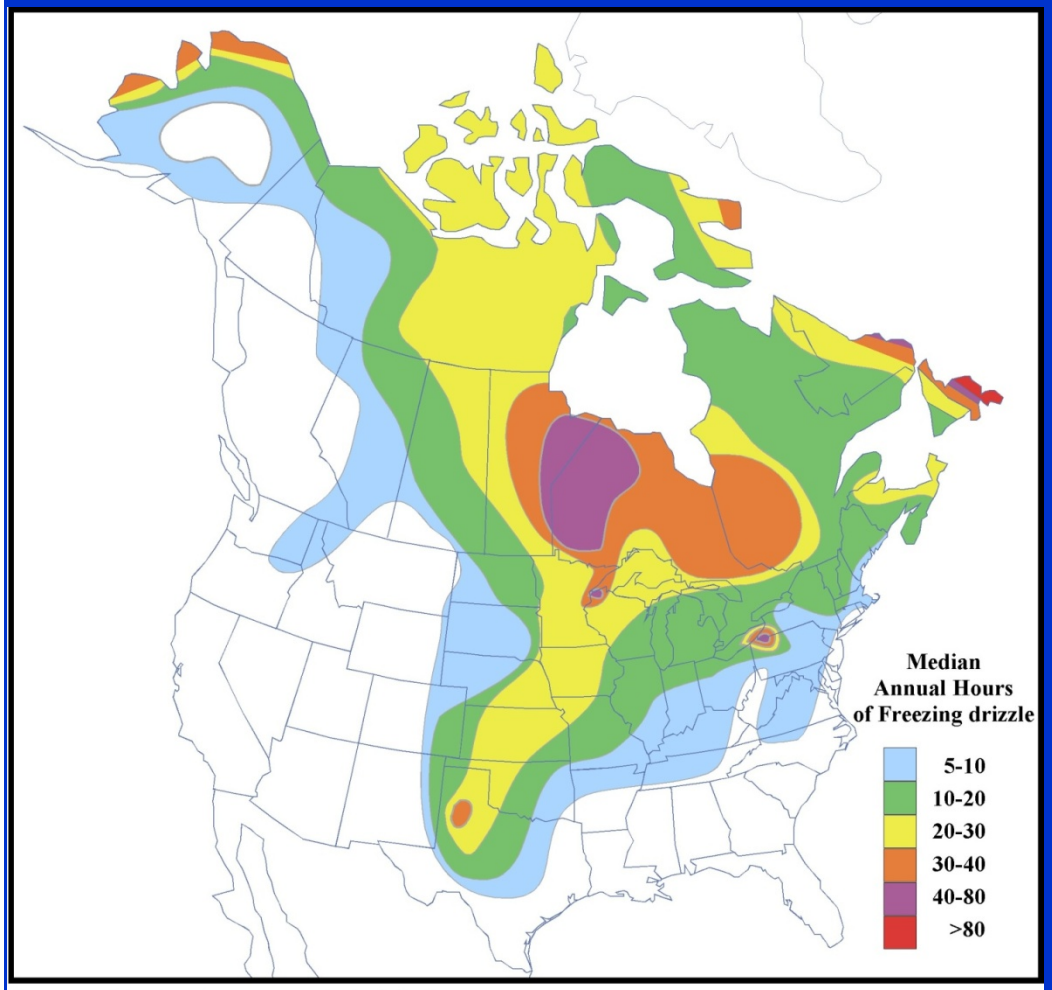
# Distribution of Freezing Rain




Courtesy of the American Meteorological Society

- Freezing rain occurs most frequently over eastern Canada and New England.
- An axis of higher freezing rain frequency extends into the southeastern US along the Appalachian Mountains.
- A second axis moves eastward from New York and Pennsylvania into Illinois.
- The frequency decreases toward Gulf of Mexico and the western Great Plain.
- Freezing rain rarely occurs west of the Rockies.

# Distribution of Freezing Drizzle

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- The distribution is very different from that of freezing rain, although both show the highest frequencies over eastern Newfoundland.
- A much larger frequencies is found over the central US and Canada, where warm air is lifted aloft over arctic air masses, creating a stratus cloud layers.
- Typically, arctic fronts originate in central Canada and move southward into Central US, where the freezing drizzle occurs.
- Freezing drizzle is rare in the western US.
- Freezing drizzle occurs twice more often before sunrise than in the afternoon hours.